ORIGINAL ARTICLE

Effects of Magnesium Oxide (MgO) Nanoparticles on the Hardness, Roughness, and SEM Investigation of Maxillofacial Silicone Elastomers: An in Vitro Study

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Abstract

Purpose: This research aimed to evaluate how different concentrations of MgO nanoparticles influence the hardness, surface roughness, and SEM investigation of VerSiltal 50 silicone elastomeric materials that vulcanize at room temperature.

Materials and Methods: Using different weight percentages of MgO nanoparticles, 60 samples were created (0%, 0.5%, and 1% by wt.). The analysis made use of thirty samples from each group. Tests for surface roughness and surface hardness were performed on two experimental groups that contained 0.5% and 1% weight of MgO nanoparticles. Descriptive statistics and analysis of variance with multiple comparison tests were used to evaluate the data, and significance was indicated by a P value < 0.05. Scanning electron microscopy was used to measure the surface topography (SEM). Energy Dispersive X-ray spectroscopy (EDS) can be used to determine the distribution of Magnesium Oxide within the VST-50 silicone matrix.

Results: Surface roughness and hardness increased as the percentage of MgO nanoparticles increased from 0.5 wt. % to 1 wt. %, compared with those in the control group. The SEM test showed a good dispersion of the nanofillers and incorporation within the polymeric matrix of silicone. It showed that there was a slight little agglomeration of Nano filler particles as filler loading increased.

Conclusion: Compared to the control group, the means for surface roughness and hardness increased significantly in the 0.5 and 1 wt.% MgO experimental groups.

Keywords: Biocompatibility; VerSilTal 50; Room Temperature Vulcanizing; Magnesium Oxide; Nanoparticles.

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1. Introduction

Numerous materials, such as silicone, poly(methyl methacrylate), poly(vinyl chloride), polyurethane, chlorinated polyethylene, and poly(methyl vinyl chloride were used to create maxillofacial prostheses [1]. Silicone elastomer may be considered the material of choice when fabricating facial prostheses due to its biocompatibility, low chemical reactivity, simplicity to manipulate, and visual transparency [2]. These materials have particular qualities that satisfy the specifications for producing facial prostheses; however, some disadvantages necessitate their improvement [3]. There has been a lot of interest in silicone elastomers' structures and properties related to maxillofacial restoration [1]. Biocompatible restorative materials must have low surface energy, adequate hardness and elasticity, sufficient tear strength to withstand daily wear and tear, and sufficient tensile strength to withstand external forces [1].

In order to create materials with better mechanical and physical qualities, nanotechnology was applied. By integrating nanoparticles into base materials, advanced and customized materials with distinct physical and mechanical properties that are not feasible in base materials can be produced. Utilizing this cutting-edge technology satisfies the needs of applications for fundamental materials [4, 5].

In one study, the mechanical properties of room-temperature vulcanized silicone were improved by reinforcing VST 50F maxillofacial silicone with 1% and 1.5 % concentrations of Nano Al_2O_3 [6]. In this study, MgO nanoparticles were Selected. MgO nanoparticles are characterized by high thermal and chemical stability [7], high sorption capacity, high electrical resistance [8], excellent catalytic activity [9], high value of hardness [10], high surface area/volume ratio [11], and biocompatibility [12].

The objective of the current study was to examine the effects of introducing MgO nanoparticles at different weight percentages (0.5 and 1 wt. %) on the surface hardness and surface roughness of VerSilTal 50 (VST-50) room-temperature vulcanizing(RTV) silicone elastomers.

The null hypothesis (H0) is that incorporating Magnesium Oxide(MgO) nanoparticles does not improve physical properties, and the alternative hypothesis (H1) is that adding Magnesium Oxide (MgO) nanoparticles improves physical properties.

2. Materials and Methods

2.1. Pilot Study

A pilot investigation was conducted to determine the ideal of Magnesium Oxide(MgO) nanoparticle concentration to add to the RTV Maxillofacial silicone. MgO nanoparticle concentrations of 0.5 and 1 weight % were chosen for the main study.

2.2. Preparation of Samples

This study compared the surface hardness and surface roughness. Molds were fabricated by custom cutting 2 and 4 mm-thick acrylic sheets (PT. Margacipta Wirasentosa, Indonesia) using a laser cutting device (JL-1612, Jinan Link Manufacturing Trading Co., Ltd., China). The upper and lower parts are made of plates 4 mm thick (sample thickness required in some tests) rather than 2 mm thick [13]. VST-50 (Factor II, lakeside, USA, cas no. F 15U138R06) is a two-part platinum RTV silicone elastomer. Part A represents the silicone base and part B represents the catalyst.

MgO nanoparticles have been used as filler particles. To prevent the spread of the MgO nanoparticles, silicone was added after weighing the MgO nanoparticles with an electronic digital balance (0.000 digits; China; part A). The modified silicon was mixed for 10 min in a vacuum mixer (Multivac 3, Degussa, Germany). To prevent the package from being sucked in, the vacuum was turned off for 3 min and then turned on again for 7 min at 360 rpm and −10 bar vacuum. To produce a homogeneous and bubble-free mixture, the silicon base (part A) or modified silicon (part A and MgO nanoparticles) with the silicon catalyst (Part B) for 5 min using a vacuum mixer [14]. An insulating substance was applied to a mold and let it dry. The silicone mixture was poured into the mold and then sealed with screws and clamps [3]. As stated by the manufacturer, silicone should be left on the bench for 24 h at 23.2 °C and 50% humidity.

After the silicone material was polymerized at room temperature (23 °C) for 24 h, the mold was opened, and the samples were carefully removed [15]. The samples were rinsed thoroughly with running water, dried with paper towels, and cleaned with a #11 scalpel blade. They were then stored under ideal conditions in a storage container (Polarbag, China) for at least 16 h before testing [15–17].

2.3. Scanning Electron Microscopy (SEM) and Energy Dispersive X-Ray Spectroscopy (EDS) Analysis

They were used to measure the surface topography (SEM) and to figure out how Magnesium Oxide Nanoparticles are distributed within the VST-50 silicone matrix (EDS).

One control sample and two experimental groups containing 0.5 % and 1 % MgO nanoparticles were tested for each analysis.

2.4. Surface Hardness Test

Thirty samples were created following ISO 7619-1:2010's standards [18]. The minimum thickness was 6 mm, and the sample size was 25 mm by 25 mm. Surface hardness was assessed in this investigation utilizing a digital Shore A durometer (HS-A, Ezitown, China) and a blunt indenter with a 1.25 mm diameter. Five dotted areas were placed on the surface of each sample. The spacing between the marking points was 6 mm. By averaging five readings, the surface hardness of each sample was determined.

2.5. Surface Roughness Test

Thirty samples were created by ISO 7619-1:2010 [18] requirements. The specimens' dimensions were the same as those of the surface hardness specimens.

The surface roughness was measured using a profilometer (TR200, China) with a precision of 0.001 mm. The device had a delicate diamond tip (surface analyzer) for tracing the contours of surface imperfections. To get three readings per sample, which was placed on a stable, hard surface, the device was set so that the stylus only touched the sample surface three different times. The stylus traveled around the designated surface (11 mm) to reach the first point. The scale of Ra's digital scale showed the reading. This parameter represented a set of individual measurements of the surface's average peak and valley [19]. The roughness value was then calculated using the average of the three measurements [20-21].

2.6. Statistical Analysis

Utilizing the Statistical Package for the Social Sciences (version 23) software, the data for this study were assessed. The following statistical analyses were carried out:

Box plots were used for descriptive statistics. Inferential analysis included an Analysis Of Variance (ANOVA) table to compare all group mean. Shapiro-Wilk test for homogeneity of variance and the Bonnferroni multiple-comparison test were performed to determine the significant differences between groups.

Statistically, a P-value of ≥0.05 is not significant, a P-value of <0.05 is significant, and a P-value of ≤0.01 is highly significant.

3. Results and

3.1. Scanning Electron Microscopy (SEM)

Figures (1, 2, and 3) show the SEM results of VST-50 silicone before and after adding 0.5% and 1% MgO nanoparticles, respectively. This test revealed that the nanoparticles were evenly distributed throughout the silicone polymeric matrix and were fully incorporated. It also revealed that there was a slight amount of nanoparticles agglomeration as filler (nanoparticles) loading increased.

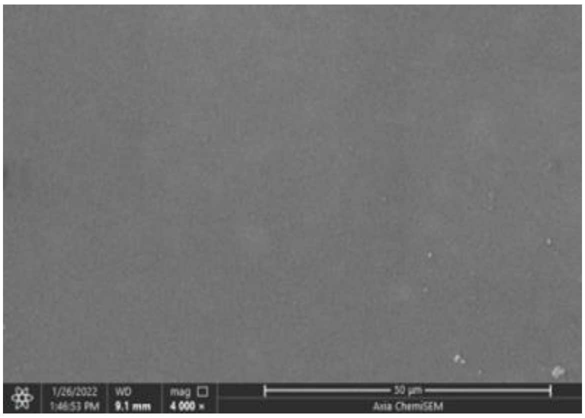

Figure 1. Image of control specimens taken using scanning electron microscopy at a magnification of 4,000

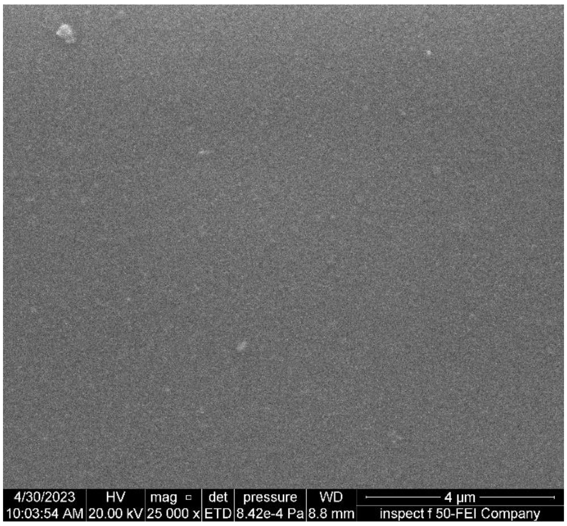

Figure 2. Scanning electron microscopy image of 0.5wt. % of Magnesium Oxide specimens; 25000 magnification

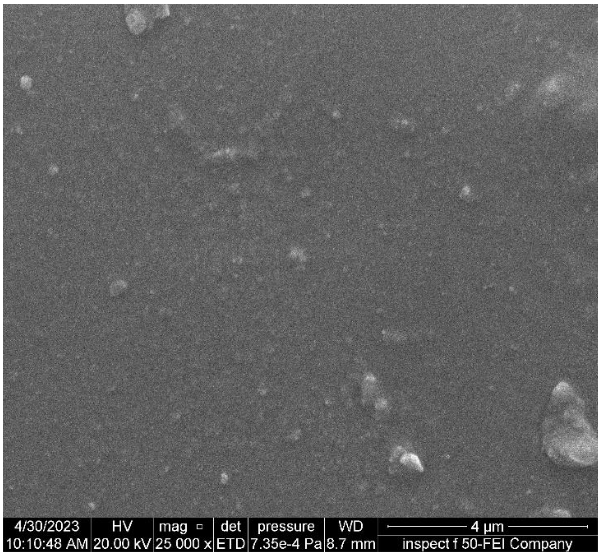

Figure 3. Scanning electron microscopy image of 1 wt. % of Magnesium Oxide specimens; 25000 magnification

3.2. Energy Dispersive X-Ray Spectroscopy (EDS)

The EDS spectrum for control, 0.5%, and 1% MgO groups (Figures 4, 5, and 6) showed the Mg peak that points toward including magnesium oxide nanoparticles into the silicone elastomer matrix.

4. Discussion

A maxillofacial prosthesis should be made of a reasonably soft material and the same hardness as the lost facial feature to be replaced. The hardness of silicone that is commercially available ranges from 16 A to 45 A on the standard A scale, but a good material should be in the 25–35 A range since that region has the resilience needed for the prosthesis to adapt to face movements [22–24]. According to the findings, adding 0.5 and 1 weight percent of MgO greatly increased the hardness. Increases in MgO nanoparticle content are correlated with higher hardness values. The dispersion of nano filler particles MgO and the creation of inter filler networks inside silicone matrices and between polymer chains are likely responsible for the rise in hardness values with the addition of 0.5 and 1% wt. MgO Nanoparticles. The penetrating force and resistance are both increased by this effect [25, 26]. Strong ionic atomic bonding in the MgO nanoparticles gives the desired material qualities of hardness and strength [27]. The shore A hardness of the reinforced samples also increased, possibly as a result of the fillers' greater adhesion to one another when their concentrations were raised, which caused them to fill the inter-aggregate spaces in the silicone matrix; such that it can resist the indentation loads [28]. Because surface abnormalities can serve as crack-nucleation sites, surface roughness is a key indicator of a material's mechanical qualities [29]. The surface roughness results demonstrate that the experimental group's average roughness increased compared to the control group. The lowest surface roughness was observed in the control group. The increasing in surface roughness being due to The MgO nanoparticles may be associated strongly with the polymeric chains even after severe conditions. If these particles were detached, an increase in the porosity of the polymer and a reduction in the hardness would be expected. So the surface roughness increase results from the formation of micro cracks and pits on the surface level of the material [30].

5. Conclusion

Under the conditions set in this study, the surface hardness and roughness increased after the addition of MgO nanoparticles to RTV VST-50 maxillofacial silicone elastomers as the concentration of MgO nanoparticles increased.

Hardness and roughness increased but were still within the acceptable range.

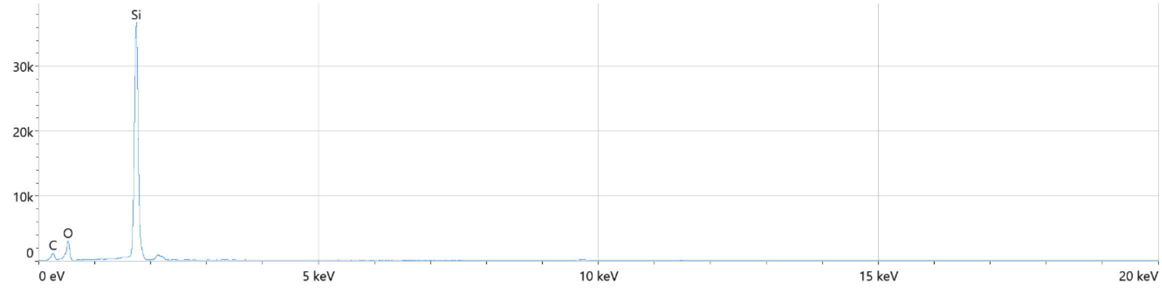

Figure 4. EDS for control specimen

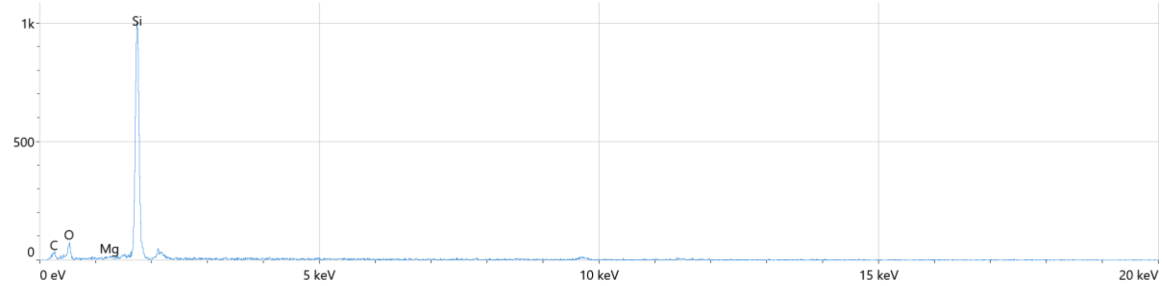

Figure 5. EDS for 0.5wt.% of Magnesium Oxide specimen

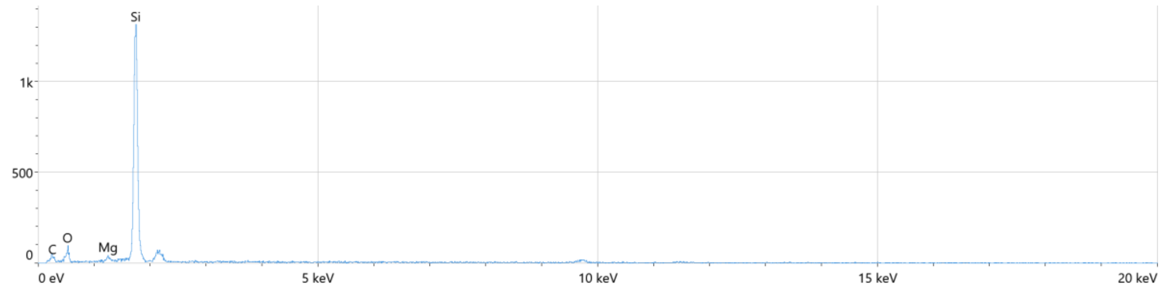

Figure 6. EDS for 1%wt. of Magnesium Oxide specimen

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